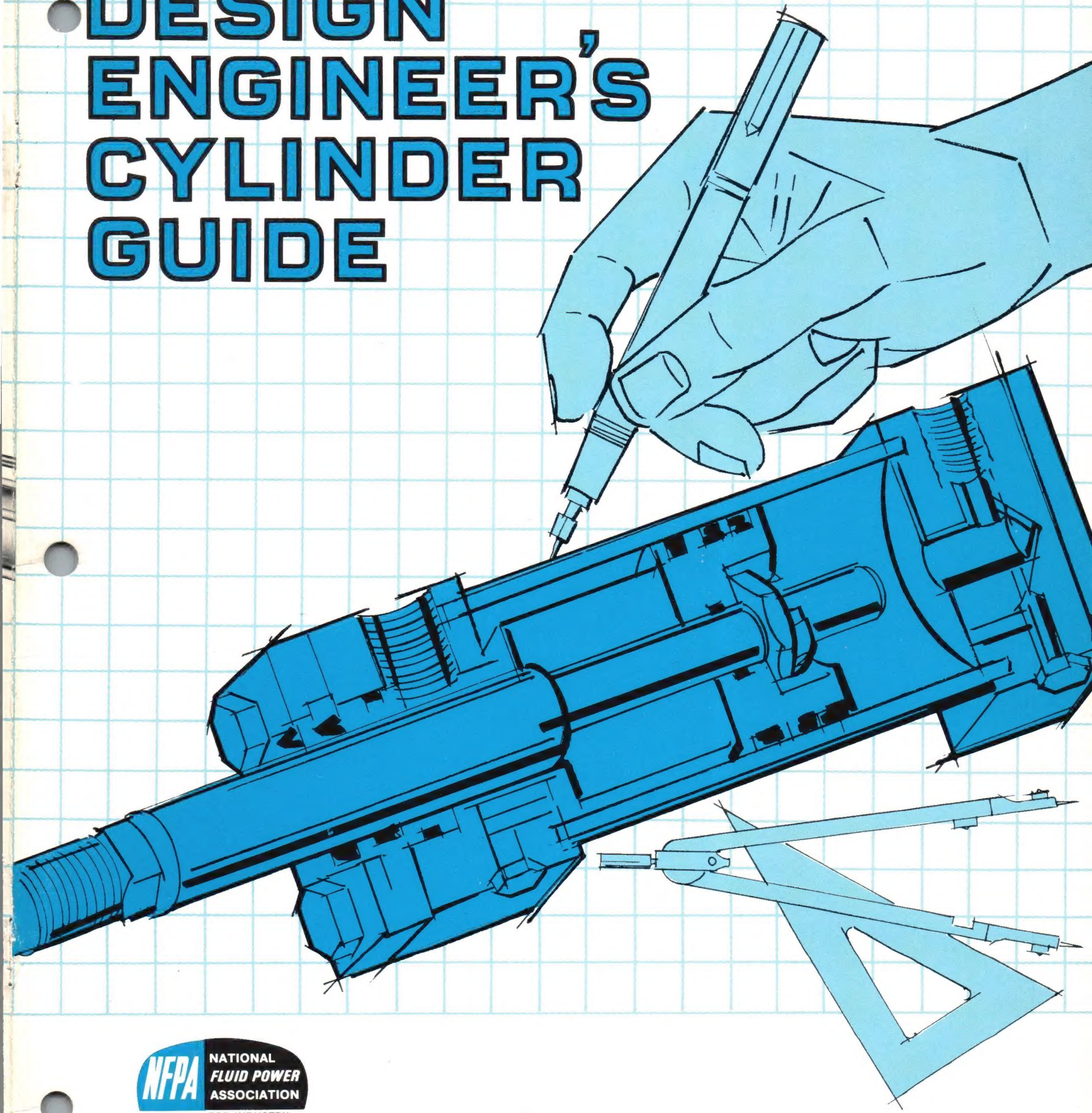
the DESIGN ENGINEER'S CYLINDER GUIDE



NATIONAL FLUID POWER ASSOCIATION
ENERGY FOR INDUSTRY

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Index

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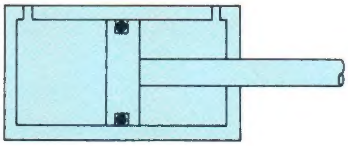
Cylinders

BASIC CYLINDER OPERATING PRINCIPLES

Cylinders are used to convert fluid power into mechanical motion. Basically, a cylinder consists of a cylindrical body, closures at each end, movable piston, and a rod attached to the piston.



When fluid pressure acts on the piston, the pressure is transmitted to the piston rod resulting in linear motion. The piston rod thrust force developed by the fluid pressure acting on the piston is easily determined by multiplying the line pressure by the piston area.

FORCE = PRESSURE × AREA or F = PA

EXAMPLE: Find the thrust force of a 4" diameter piston operating with a line pressure of 100 psi.

The piston area has to be determined first to solve this problem. In the case of a 4" diameter piston, the area equals 12.57 square inches. Since a pressure of 100 psi acts on each square inch, the total thrust force will be 100 × 12.57 or 1257 lbs.

When calculating the pull force of a cylinder, the area covered by the piston rod must be subtracted from the total area of the piston. The pressure does not act on the area covered by the piston rod.

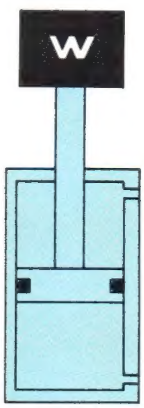
On page 9 and page 10, tables are provided to save mathematical calculations for determining thrust force, pull force, and cylinder speed.

TYPES OF CYLINDERS

Standard cylinders have been designed to meet the wide range of applications in today's industry. The following types of cylinders provide an overview of what is available to the design engineer.

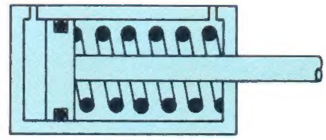
Single Acting Cylinder

The single acting cylinder is pressurized at one end only, with the opposite end vented to atmosphere through a breather filter (air cylinder) or vented to a reservoir (hydraulic cylinder). The return stroke of the cylinder is accomplished by some external means.



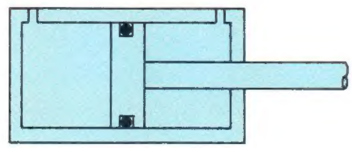
Spring Return Cylinder

The spring return cylinder is normally considered a single acting cylinder. The operation of this type of cylinder is the same as a single acting cylinder, except that a spring is used to accomplish the return stroke.



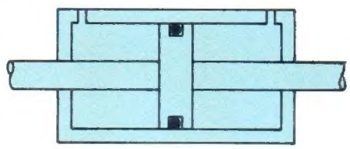
Double Acting Cylinder

The most familiar double acting cylinder is the single rod end. This type of cylinder provides power in both directions, with a pressure port at either end. Single rod end cylinders exert greater forces when extending than when retracting since the piston area on the blind end is larger than the piston area on the rod end (due to the area covered by the piston rod).



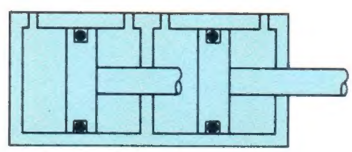
Double Rod End Cylinder

The double rod end cylinder is used when it is necessary for the cylinder to exert equal force and operate at equal speed in both directions. It also can be used to operate limit valves or switches.



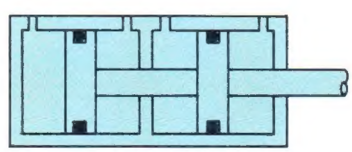
Positional or Duplex Cylinder

This type of cylinder is designed on the force multiplier principle. It enables the user to attain higher thrust forces in smaller bore cylinders. The high thrust force of this cylinder is limited by the length of stroke of the rear cylinder, since the piston rods are not connected.

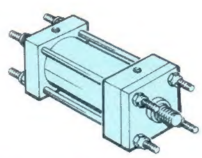
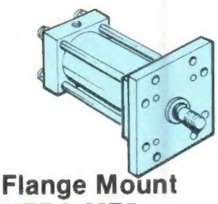
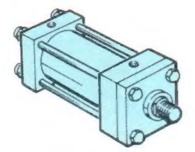
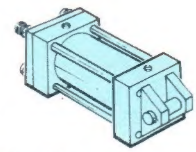
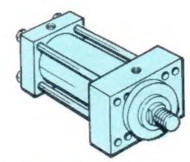
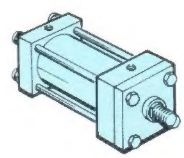
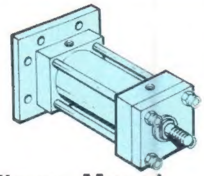
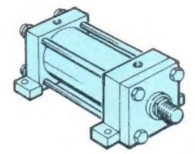
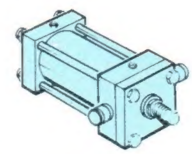
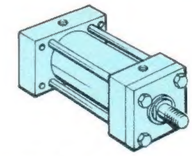
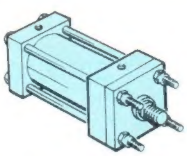
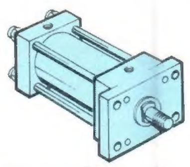
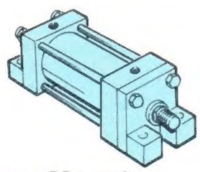
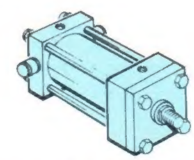
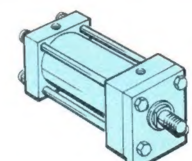
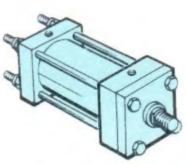
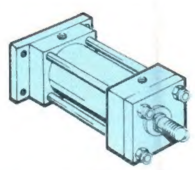
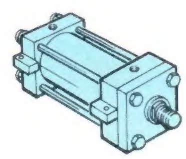
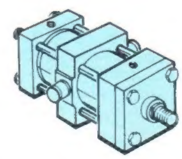
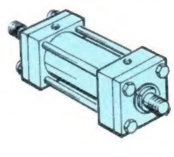


Tandem Cylinder

A tandem cylinder consists of two cylinders mounted in line with the pistons, connected by a common piston rod. The main advantage of this cylinder is the multiplication of force, during the entire stroke, without requiring higher operating pressures or larger bores.



Standard NFPA Mountings

 **Tie Rd Mount** **NFPA MX1**	 **Flange Mount** **NFPA MF5**	 **Side Mount** **NFPA MS4**	 **Pin Mount** **NFPA MP1**	 **Solid Flange** **NFPA ME5**
 **No Mount** **NFPA MX**	 **Flange Mount** **NFPA MF6**	 **Lug Mount** **NFPA MS2**	 **Trunnion Mount** **NFPA MT1**	 **Solid Flange** **NFPA ME6**
 **Tie Rod Mount** **NFPA MX3**	 **Flange Mount** **NFPA MF1**	 **Lug Mount** **NFPA MS7**	 **Trunnion Mount** **NFPA MT2**	 **Key Mount**
 **Tie Rod Mount** **NFPA MX2**	 **Flange Mount** **NFPA MF2**	 **Lug Mount** **NFPA MT3**	 **Trunnion Mount** **NFPA MT4**	 **Double Rod End** **NFP MDX**

DESIGN INFORMATION

Tie Rod Mount

When using tie rods extended on the rod end, the best application is a tension load. For a thrust load application, the tie rods should be extended on the blind end of the cylinder. Tie rod mounts are suited for many applications, but it should be noted that they are not as rigid as flange mounted cylinders and often require additional support for long stroke applications.

Flange Mount

The Flange Mount is one of the strongest, most rigid methods of mounting. With this type of mount, there is little allowance for misalignment. When long strokes are required, the free end opposite the mounting should be supported to prevent sagging and possible binding of the cylinder. When the cylinder is used in a thrust load application, a blind end flange should be used. For tension applications, rod end flange mounts should be used.

Side and Lug Mounts

The side or lug mounted cylinder provides a fairly rigid mount. This type of mount can tolerate a slight amount of misalignment when the cylinder is fully extended, but as the piston moves toward the blind end, the tolerance for misalignment decreases. It is important to note that if the cylinder is used properly (without misalignment), the mounting bolts are either in simple shear or tension without compound stresses.

Pin and Trunnion Mount

All pin and trunnion mounted cylinders need a provision on both ends for pivoting. This type of mounting is designed to carry shear loads and requires that the trunnion or pivot pins are rigidly held by closely fit bearings for the entire pin length.

Solid Flange Mount

The solid flange mount is the strongest, most rigid method of mounting a cylinder. Industry standards for this type of mounting only cover 3-1/4" through 8" bore cylinders.

Key Mount

The key mount retainer plate is a mounting option designed to add stability to foot and side mounted cylinders. The retainer plate is extended below the mounting surface of the cylinder. This extension may be fit into a milled keyway, eliminating the need for welded keys or locator pins.

Double Rod End Cylinders

Double rod end cylinders are available in every mounting style except the clevis mount. It should be noted by the designer that when a double flange mount is required, there will be tie rod nuts protruding on one end.

Mounting Modifications

SPECIAL CYLINDER MOUNTINGS

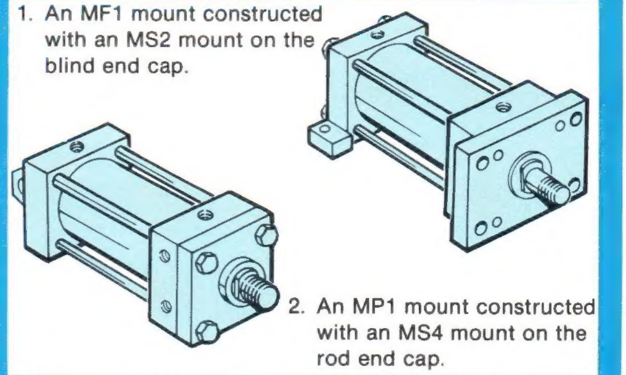
The standard NFPA (National Fluid Power Association) mountings satisfy a wide range of mounting applications and can be easily modified to suit specific design requirements. As a machine or equipment designer, you may encounter various situations where a standard or a modified standard mounting will not satisfy your design requirements. Milwaukee Cylinder specializes in meeting your needs in this area by providing cylinders custom designed to suit your specific applications.

The cylinder pictured at the bottom of this page is an example of Milwaukee Cylinder's ability to meet the needs of today's industry in the area of special mountings. This special pumping unit was designed to separate two hydraulic systems, preventing contamination of the primary system. A base plate mounting was designed that would not only maintain the alignment of the pumping unit, but also be adaptable to an existing machine member.

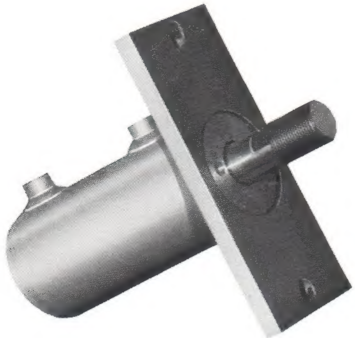
For information on what data is required by Milwaukee Cylinder to develop a design to suit your specific requirements, contact either your local Milwaukee Distributor or the factory.

COMBINED MOUNTINGS

Milwaukee Cylinder offers the designer the ability to combine standard mountings to meet special design requirements. Some examples of this are:

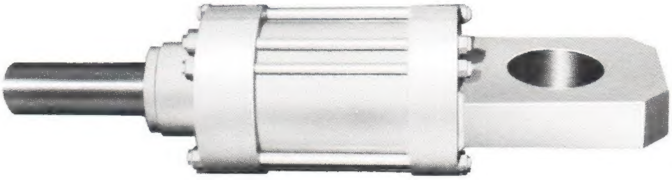


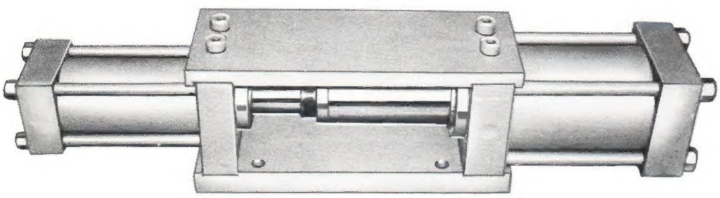
These and other combinations can be readily made from standard parts. If you are unsure of a possible combination or its suitability to your application, consult your local Milwaukee Distributor or the factory.



When it comes to special cylinders, Milwaukee Cylinder is not limited to tie rod constructed cylinders. This cylinder, which incorporated a number of special features, was designed for use on farm equipment. It features a threaded rod bushing for easy removal of the rod and piston seals, a modified NFPA mount MF1 to suit the design requirement of the customer, welded construction, and welded half coupling ports were required so that this cylinder would be interchangeable with equipment already in the field.

We are proud of our role as a quality supplier of cylinders to many different areas of industry. This cylinder was designed for a foundry application that required a special mounting because of clearance problems with existing equipment. Milwaukee Cylinder satisfied the customer's requirements with round end caps to provide the required clearance, multiple tie rods for added strength, and a special mounting to the customer's specifications.





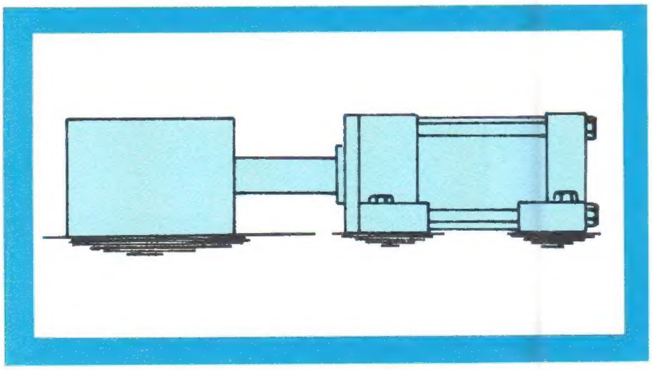
If standard cylinders won't do the job, we're specialists in engineering cylinders that will perform the functions that you require. This special pumping unit used on marine vessels was designed to separate the shipboard and mast hydraulic fluid systems. Cylinders used on a marine vessel to raise and lower the mast are subject to salt water contamination. To prevent contamination of the shipboard system an independent hydraulic system is required for the mast. This cylinder acts as a pump operated off of the shipboard system, to provide hydraulic pressure for the mast system on the marine vessel.

Cylinder Loading

MOVING LOAD

Sliding Load

Cylinders perform a wide variety of applications and are often used in place of larger, more expensive mechanical systems. One such application is when a cylinder is used to move a high friction sliding load. Some examples of this are: machine slides, pallet shuttle systems on automated machinery, milling machine tables, and grinder tables.

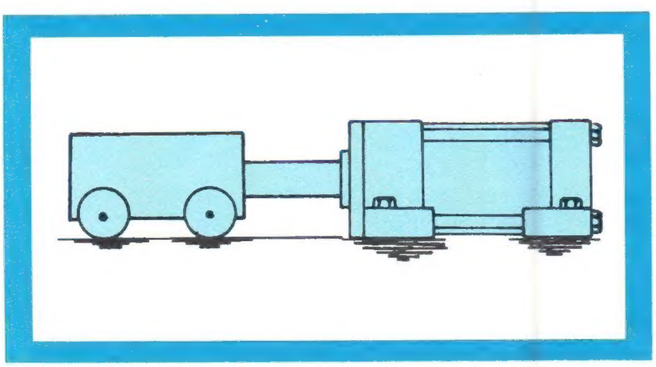


There are a number of things to consider when sizing a cylinder for a sliding load application. These include the unit weight (load), lubrication, and required speed. For applications where there is light lubrication, the cylinder should provide a thrust force capable of moving a load equal to 50% to 75% of the actual load. Once in motion, a thrust force capable of moving 20% of the actual load weight is adequate.

Because air is a compressible medium, air cylinders should not be used for slow or controlled feed or motion in a sliding load application. The designer should be aware that a jerky motion will result if an air cylinder is used to perform this type of work. Because oil is non-compressible, a hydraulic cylinder with a metered out speed control would be more effective. For indexing applications, from one positive stop to another, air cylinders usually provide better response and more rapid action than hydraulic cylinders.

Rolling Load

Cylinders can be used to move rolling loads or loads which are moved on low friction bearings. For this type of application, the cylinder should have a thrust force capable of moving a load equal to 10% of the actual load. When using a cylinder to move a rolling load, some means of deceleration at the end of the cylinder stroke should be used to prevent the momentum of the load from damaging either the cylinder or the machine.

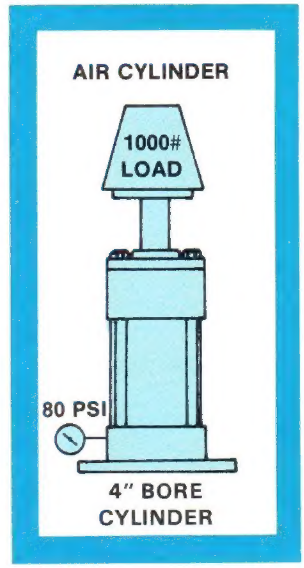


CYLINDERS FOR LIFTING

Vertical Lifting

Air cylinders must be sized to have more force than needed to just balance the load it must move. The more the cylinder is oversized, with respect to the load, the faster it can move the load (this is not true of hydraulic cylinders).

In the figure at the right, the cylinder has enough upward force to just balance the weight of the load. It cannot move the load upward, it can only hold it from dropping. To start the load in motion it will have to have additional force. This can be provided by increasing the air pressure to more than 80 psi or by use of a larger bore cylinder.

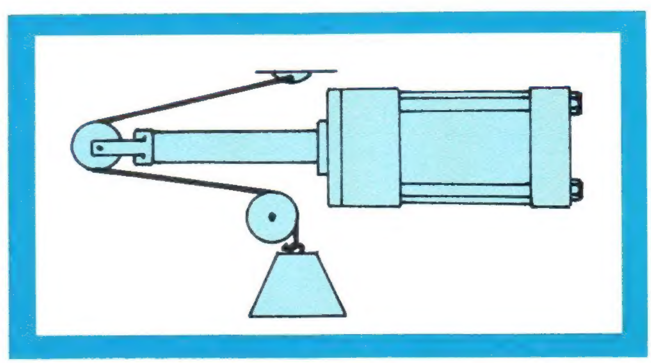


The exact speed of an air cylinder cannot be calculated. Air cylinder sizing depends on the degree of overpowering to move the load, valving, piping, and other factors which usually are unknown and cannot be measured. For further information on air cylinder sizing and speed, refer to page 10.

An air cylinder should not be used for a platform or hoist lift application. If the lift is stopped in mid stroke, it will have a tendency to drift due to the compressibility of air. A hydraulic system or air over oil system should be used in these types of applications, since force applied to a confined liquid exhibits about the same effect of rigidity as a solid.

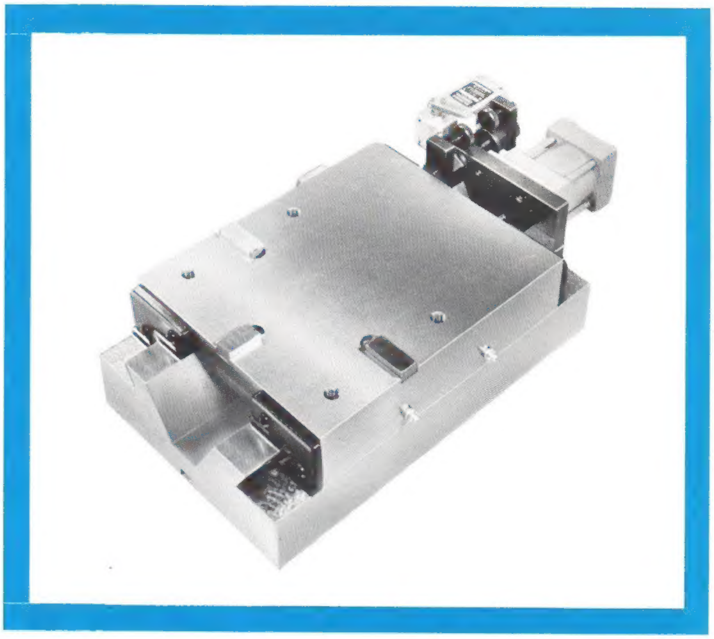
Differential Lift

The differential lift gives the user a 2:1 mechanical advantage over the straight lift. The bore size required for a differential lift is two times that of a straight lift (vertical lift), but the stroke required would be only one half of what is required for a straight lift performing the same application.



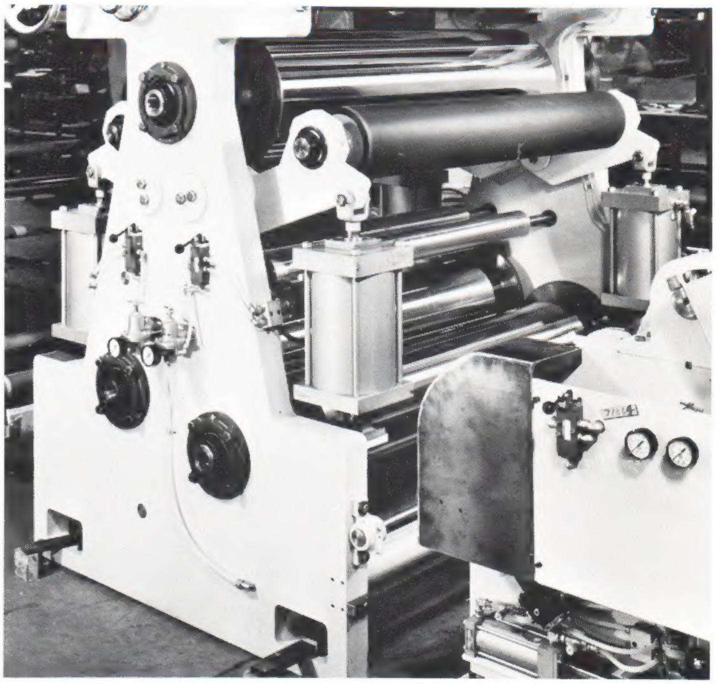
When space is a problem, this cylinder application provides an ideal method for performing a lifting function. The shorter length and larger bore are design advantages which must be considered.

Special Load Applications



Reciprocating Cylinder

The historical means for controlling back and forth motion on the cross slides of milling and grinding machines has been through the use of complicated mechanical linkages. Milwaukee helped engineer a back and forth function through the use of a cylinder coupled directly to the sliding bed. The back and forth motion is accurately controlled by means of a limit switch with adjustable trip dogs. The entire special controlling mechanism, cylinder, and interfacing assembly was produced at Milwaukee Cylinder.



Compensating Pressure Cylinders

The machine illustrated on the right is a coater and laminator used in packaging production. There are four large Milwaukee produced cylinders on this machine used to provide a constant vertical pressure on two sets of rollers. The pressure has to be extremely accurate or the thickness of the coatings will vary. Although the cylinders used are standard, Milwaukee engineers helped in the design of the hydraulic control system that senses the slightest change in roller pressure and immediately adjusts the cylinder motion to compensate for it.

Controlled Drift Cylinder

This cylinder was specially designed to lift a milling machine table with an allowable drift of only .002" max. for the entire length of the cylinder stroke. The design specifications were critical. Milwaukee engineers came up with a cylinder that has a recessed retainer plate and rod bushing with a tube that is bored out so that a rod end cap is not necessary. An unusual tie rod design places them through the entire length of the barrel and then the flange. The cylinder is ported through the mounting flange blind end.

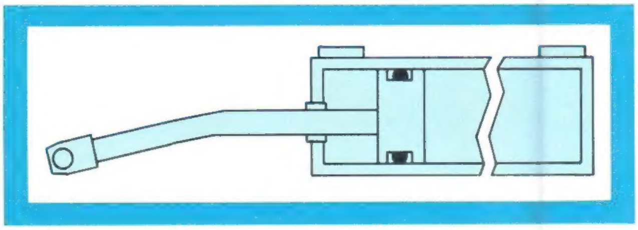
Cylinder Sizing

ROD SIZE

Rod Buckling

Correct rod size selection is an important factor in sizing a cylinder for an application. If the piston rod diameter is too small in relation to the load column, failure or rod buckling is likely to occur.

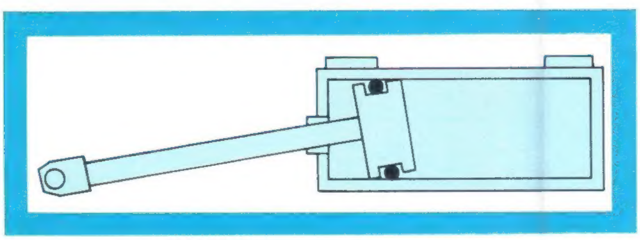
The standard rod for each bore size that Milwaukee Cylinder manufactures is sufficient to carry the maximum tension force that the cylinder is capable of producing. It is in compression applications that the column strength needs to be considered. For proper rod size selection in compression applications, refer to page 9 "Rod Size Selection".



Rod Bearing Failure

Side load is the most common cause of rod bearing failure. Milwaukee Cylinder has designed its standard line of cylinders to operate with a minimum amount of side load. When mounting a cylinder, it is critical that the alignment is checked both in the extended and the retracted positions. When the rod is fully extended, extensive leverage can be developed. If a side load condition exists, it will cause the piston to score the barrel and rapidly reduce the effective life of the rod bushing.

The designer has three methods which can be used to either eliminate or reduce the effects of side load. The first is to use a pin or trunnion mounted cylinder so as to move with the side load. The second is to guide the load and the piston rod, which will eliminate the side load condition. The third solution is to use a cylinder with more stroke than necessary to perform the function. This will increase the distance between the two bearing areas of the cylinder (the piston and rod bushing), reducing the overall effect of the side load condition.

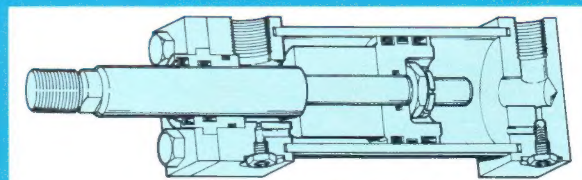


Stop Tube

The use of a stop tube is the preferred method for reducing piston and bearing loads on long stroke cylinders. It is also used to prevent jack-knifing or buckling of horizontally mounted cylinders used in long stroke compression applications.

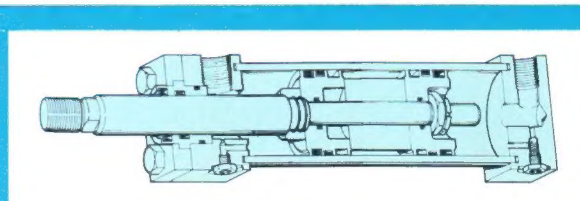
For reducing bearing loads on the rod, a stop tube is more effective, less costly, and lighter weight than an oversized piston rod. A stop tube is placed between the piston and rod end cap to restrict the extension of the rod. This space between the two bearing areas provides additional strength and support for the extended rod.

At Milwaukee Cylinder, we offer two stop tube designs. The single piston stop tube design is common to all cylinders except cushion rod end air cylinders.



Single Piston Stop Tube

A stop tube will increase the overall length of the cylinder and will alter the mounting dimensions on most models by the length of the stop tube.

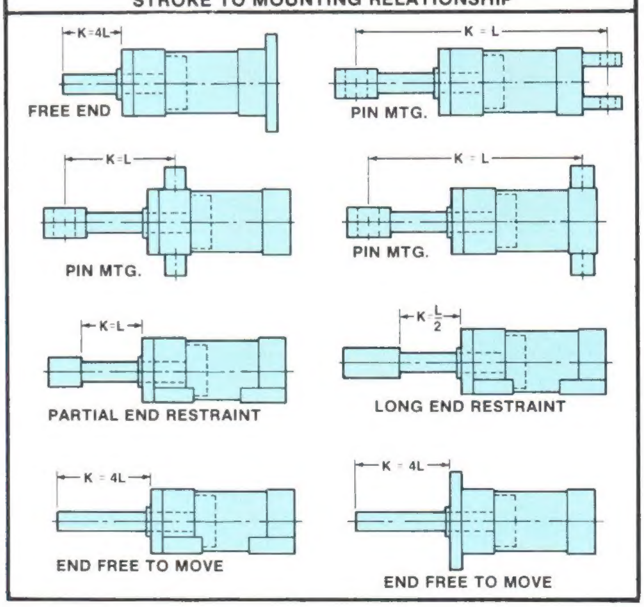


Double Piston Stop Tube

The second stop tube design is the double piston stop tube. This stop tube is primarily used for cushion rod end air cylinders. Unlike the single piston stop tube design, the double piston stop tube provides additional strength for excessive side loading and adds additional bearing area to the cylinder.

To determine if a stop tube is necessary for a cylinder application, the value of "K" has to be determined (refer to table 1). If the required cylinder has a "K" value in excess of 40", a stop tube is required. For each 10" increment or fraction thereof in excess of 40", one inch of stop tube is recommended.

STROKE TO MOUNTING RELATIONSHIP



When mounting long stroke cylinders, care should be taken to assure cylinder alignment over the entire length of stroke. The use of external guides or swivel bushings is recommended to reduce side load conditions and prolong the cylinder's service life.

Cylinder Sizing

The selection of the correct rod size is one of the most important factors in sizing a cylinder. The standard rod for each bore size that Milwaukee Cylinder manufactures is sufficient to handle the maximum tension force that the cylinder is capable of producing. It is primarily in compression and long stroke, high thrust applications that the column strength needs to be considered.

The following steps should be used to determine the proper rod size for an application:

1. Select the cylinder bore size required from Table 4 based on the required cylinder thrust force and the operating line pressure at the cylinder.
2. Determine the length between mounting points or "L" as shown on Table 1.
3. Based on the distance between mounting points ("L"), determine the value of "K" as shown on Table 1.
4. Using the thrust force and the developed "K" dimension, refer to Table 2 to select the proper rod size.
5. If an oversized rod is required, re-check the overall length dimension ("K") in step 1 and confirm your previous rod size selection.

To determine the cylinder pull (tension), stroke force, or displacement, deduct the force or displacement corresponding to the rod size in Table 3 from the force or displacement corresponding to the bore size shown in Table 4.

TABLE 2 — VALUE OF "K" IN INCHES

Thrust Force In. Lbs.	PISTON ROD DIAMETER												
	5/8"	1"	1 3/8"	1 3/4"	2"	2 1/2"	3"	3 1/2"	4"	4 1/2"	5"	5 1/2"	7"
400	35	84	134										
700	30	68	119										
1000	26	60	105	156	190								
1400	24	54	93	144	175	244	308						
1800	23	48	84	127	160	230	294	366					
2400	18	45	75	114	145	214	281	347					
3200	16	40	68	103	131	196	262	329	398				
4000	12	38	63	93	119	174	240	310	373	446			
5000	9	36	60	87	112	163	225	289	359	426			
6000		30	56	82	102	152	209	274	342	411	476		
8000		25	51	76	93	136	186	244	310	375	448		
10000		21	45	70	89	125	172	221	279	349	412		
12000		17	41	64	85	117	155	210	270	326	388	455	
16000			35	57	75	110	141	188	233	291	350	421	
20000			28	52	66	103	136	173	218	270	325	385	
30000				39	56	87	120	156	190	232	285	330	
40000				24	43	75	108	142	177	210	248	293	
50000					30	66	97	131	165	201	234	268	408
60000						57	88	119	154	190	226	256	384
80000						36	71	104	136	170	204	240	336
100000							56	91	120	154	199	224	324
120000							45	76	108	146	174	207	313
140000								64	98	129	162	194	301
160000								47	87	118	149	182	279
200000									65	98	131	160	260
250000										72	109	143	236
300000											85	120	212
350000											53	100	195
400000												72	182
500000													152
600000													114
700000													70

TABLE 3 — DEDUCTIONS FOR PULL STROKE FORCE AND DISPLACEMENT

Piston Rod Dia.	Piston Rod Area	Cylinder Force In Pounds For Various Pressures												Displacement Per Inch of Stroke		
		50 psi	60 psi	80 psi	100 psi	200 psi	250 psi	500 psi	750 psi	1000 psi	1500 psi	2000 psi	3000 psi	Oil Gallons Displaced	Pressure Air Cubic Ft. Displaced	Free Air Cubic Ft. At 80 psi
5/8	.307	15	18	25	31	61	77	154	230	307	461	614	921	.00133	.00018	.00116
1	.785	39	47	63	79	157	196	393	589	785	1178	1570	2355	.00340	.00045	.00290
1 3/8	1.485	74	89	119	149	297	371	743	1114	1485	2228	2970	4455	.00643	.00086	.00554
1 3/4	2.405	120	144	192	241	481	601	1203	1804	2405	3608	4810	7215	.01041	.00139	.00895
2	3.142	157	189	251	314	628	786	1571	2357	3142	4713	6284	9426	.01360	.00182	.01172
2 1/2	4.909	245	295	393	491	982	1227	2455	3682	4909	7364	9818	14730	.02125	.00284	.01829
3	7.069	353	424	566	707	1414	1767	3535	5302	7069	10600	14140	21210	.03060	.00409	.02635
3 1/2	9.621	486	577	770	962	1924	2405	4811	7216	9621	14430	19240	28860	.04165	.00557	.03588
4	12.57	628	754	1006	1257	2514	3143	6285	9428	12570	18860	25140	37710	.05442	.00727	.04683
4 1/2	15.90	795	954	1272	1590	3180	3975	7950	11920	15900	23850	31800	47700	.06883	.00920	.05926
5	19.64	982	1178	1570	1962	3924	4909	9818	14726	19635	29452	39270	58905	.08500	.01137	.07324
5 1/2	23.76	1188	1426	1901	2376	4752	5940	11880	17820	23760	35640	47520	71280	.10286	.01375	.08857
7	38.48	1924	2309	3080	3848	7700	9620	19240	28860	38480	57720	76960	115400	.1668	.02227	.1437
8	50.27	2514	3016	4022	5027	10050	12570	25135	37700	50270	75400	100500	150810	.2177	.02909	.1875
9	63.62	3180	3817	5090	6362	12720	15900	31810	47720	63620	95430	127200	190860	.2753	.03682	.2371
10	78.54	3927	4712	6283	7854	15710	19640	39270	58900	78540	117810	157100	235620	.3396	.04545	.2925

TABLE 4 — THRUST FORCE AND DISPLACEMENT

Cylinder Bore	Piston Area	Cylinder Force In Pounds For Various Pressures												Displacement Per Inch of Stroke		
		50 psi	60 psi	80 psi	100 psi	200 psi	250 psi	500 psi	750 psi	1000 psi	1500 psi	2000 psi	3000 psi	Oil Gallons Displaced	Pressure Air Cubic Ft. Displaced	Free Air Cubic Ft. At 80 psi
1 1/2	1.767	88	106	141	177	353	442	884	1325	1767	2651	3534	5301	.00765	.00102	.00657
2	3.142	157	189	251	314	628	786	1571	2357	3142	4713	6284	9426	.01360	.00182	.01185
2 1/2	4.909	245	295	393	491	982	1227	2455	3682	4909	7364	9818	14730	.02125	.00284	.01829
3 1/4	8.296	415	498	664	830	1659	2074	4148	6222	8296	12440	16590	24890	.03591	.00480	.03091
4	12.57	629	754	1006	1257	2514	3143	6285	9428	12570	18860	25140	37710	.05442	.00727	.04682
5	19.64	982	1178	1571	1964	3928	4910	9820	14730	19640	29460	39280	58920	.08502	.01137	.07324
6	28.27	1414	1696	2262	2827	5654	7068	14140	21200	28270	42400	56540	84810	.12230	.01636	.10540
7	38.49	1925	2309	3079	3849	7698	9623	19240	28870	38490	57740	76980	115500	.16660	.02227	.14350
8	50.27	2514	3016	4022	5027	10050	12570	25140	37700	50270	75400	100500	150800	.21760	.02909	.18740
10	78.54	3927	4712	6283	7854	15710	19640	39270	58900	78540	117800	157100	235600	.34000	.04545	.29280
12	113.1	5655	6786	9048	11310	22620	28280	56550	84820	113100	169600	226200	339300	.48960	.06545	.42160
14	153.9	7695	9234	12310	15390	30780	38480	76950	115400	153900	230800	307800	461700	.66620	.08906	.57370
16	201.1	10060	12070	16090	20110	40220	50280	100600	150800	201100	301600	402200	603300	.8706	.1164	.7499
18	254.5	12720	15270	20360	25450	50900	63620	127200	190900	254500	381800	509000	763500	1.102	.1473	1.032
20	314.2	15710	18850	25140	31420	62840	78550	157100	235600	314200	471300	628400	942600	1.360	.1818	1.172

Cylinder Force and Speed

Air Cylinder Force

An air cylinder must be oversized to move a load. As illustrated on page 4, a 4" bore air cylinder will balance a 1000 pound load with 80 psi of air pressure. To move this load at a slow rate of speed, the cylinder must be oversized.

The designer should remember that when calculating cylinder force on the return (pull) stroke, the rod area must be deducted from the piston area. When a double rod end cylinder is used, deduct for both directions of stroke when calculating the thrust force.

Air Cylinder Speed

The exact speed of an air cylinder cannot be calculated. Air cylinder sizing depends on the degree of overpowering required to move the load at the desired speed, valving, piping, and other factors which usually are unknown and cannot be measured.

When a fast speed is required, the bore size and line pressure should be twice that which is needed to balance the load resistance. The lines to the valve and cylinder should be as short as possible. When selecting the directional valve to be used in an air application, the orifice of the valve should be equal to the cylinder port size. The air cylinder speed chart shows the proper port size under average conditions.

Note: The Air Cylinder Speed Chart (upper right) is based on average conditions. Conditions where the cylinder is operating at twice the thrust force required and a line pressure of 80 to 100 psi.

AIR CYLINDER SPEED

	Actual Valve Orifice Size							
Bore	**1/32**	**1/16**	**1/8**	**1/4**	**3/8**	**1/2**	**3/4**	**1**
1 1/8	5	12	28	85				
1 1/2	3	7	16	50	125			
2	1	4	9	28	70	112		
2 1/2		2	6	18	45	72	155	
3 1/4			3	9	22	36	78	165
4			2	7	17	28	60	130
5			1	4	11	18	40	82
6				3	7	12	26	55
8				1	4	7	15	32
10					2	4	9	20
12					1	3	6	14

Above Figures are in Inches Per Second

Hydraulic Cylinder Force

Table 4 on page 9 shows the thrust force developed by various bore diameters when working at various pressures. These figures do not include a factor covering a reduction in force due to seal or packing friction in the cylinder. This type of friction is estimated to affect the cylinder thrust force by 10%. Additional pressure must be developed by the pump not only to overcome frictional loss, but also flow losses in the circuitry. The engineer should realize that the useable pressure in the cylinder may be from 10% to 25% less than the pump and relief valve gauge reading.

Hydraulic Cylinder Speed

Figures shown in the body of this chart are cylinder rod travel speeds in inches per minute. The extension speeds represent the net piston area for the various rod diameters shown.

HYDRAULIC CYLINDER SPEEDS

Piston Dia.	Rod Dia.	1 GPM	3 GPM	5 GPM	8 GPM	12 GPM	15 GPM	20 GPM	25 GPM	30 GPM	40 GPM	50 GPM	75 GPM
1 1/2	None	130	392	654	1034								
	5/8	158	476	792	1265								
	1	235	706	1176	1880								
2	None	73	221	368	588	883	1120						
	1	97	294	490	782	1175	1465						
	1 3/8	139	418	697	1115	1673	2090						
2 1/2	None	47	131	235	376	565	675	940	1175				
	1	56	168	280	448	672	840	1120	1400				
	1 3/8	67	203	339	542	813	1015	1355	1695				
	1 3/4	92	277	463	740	1110	1385	1850	2310				
3 1/4	None	28	83	139	223	334	417	557	696	836	1115		
	1 3/8	34	102	170	271	407	510	680	850	1020	1360		
	1 3/4	39	118	196	313	472	588	784	980	1176	1568		
	2	44	134	224	358	537	672	896	1120	1344	1792		
4	None	18	55	92	147	220	276	368	460	552	736	920	
	1 3/4	22	68	113	182	273	339	452	565	678	904	1130	
	2	24	73	122	196	294	366	488	610	732	976	1220	
	2 1/2	30	90	150	241	362	450	600	750	900	1200	1500	
5	None	12	35	58	94	141	174	232	290	348	464	580	870
	2	14	42	70	112	168	210	280	350	420	560	700	1050
	2 1/2	16	47	78	125	188	235	315	390	470	630	780	1170
	3	18	55	92	147	220	275	365	460	550	730	920	1380
	3 1/2	22	66	111	178	266	333	444	555	665	888	1110	1665
6	None	8	24	41	65	98	123	162	202	245	320	405	606
	2 1/2	10	30	50	79	118	150	200	250	300	400	495	750
	3	11	33	54	87	130	165	206	270	325	435	545	810
	3 1/2	12	37	62	99	148	185	245	310	370	495	615	830
	4	15	44	73	117	176	220	295	365	440	585	735	1095
7	None	6	18	30	48	72	90	120	150	180	240	300	450
	3	7	22	37	59	88	110	145	185	220	295	365	555
	3 1/2	8	24	40	64	96	120	160	200	240	320	400	600
	4	9	27	45	71	107	135	180	225	270	360	445	675
	4 1/2	10	31	51	82	122	153	205	255	305	410	515	765
	5	12	37	61	98	147	185	245	305	370	490	615	915
8	None	4	14	23	36	55	69	92	115	135	185	230	345
	3 1/2	5 1/2	17	28	45	68	85	115	140	170	230	285	420
	4	6	18	30	49	73	90	122	150	180	240	305	450
	4 1/2	6 1/2	20	33	53	80	100	135	165	200	265	335	495
	5	7 1/2	22	38	60	90	114	150	185	225	300	375	555
	5 1/2	8 1/2	26	43	70	104	129	172	215	255	345	430	645
10	None	3	9	15	23	35	44	60	73	88	115	145	220
	4 1/2	3 1/2	11	18	29	44	55	75	92	111	150	185	275
	5	4	12	20	31	47	60	80	100	120	155	195	300
	5 1/2	4 1/2	13	21	34	50	63	84	105	132	165	210	315
	7	5 1/2	17	29	46	69	87	115	145	174	230	285	435

SPECIAL CYLINDER CASE HISTORY

Snubber cylinders for nuclear power station.

- 1,000,000 pound, 10" bore, 17,000 psi
- 2,000,000 pound, 14" bore, 17,000 psi

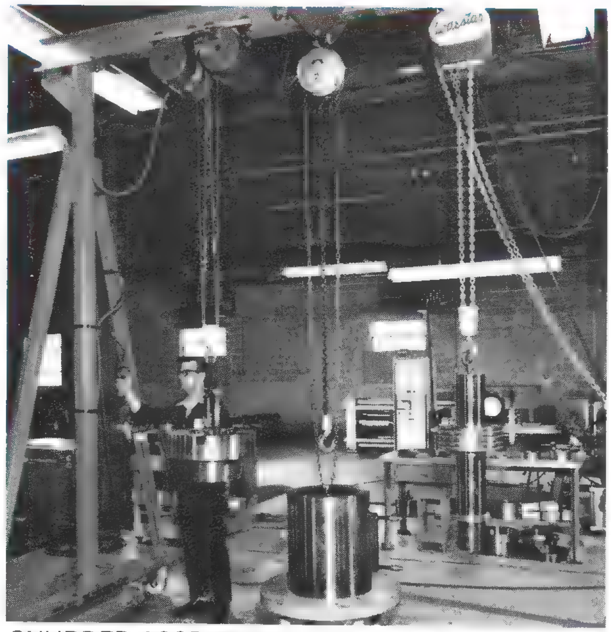
These cylinders were designed for use as snubbers to protect the piping of an atomic power plant against seismic shock. Located between the steam generator and the reactor within a concrete containment vessel. A velocity fuse, or valve, senses the speed of the cylinder. If the power plant is subjected to a pipe rupture or seismic shock in excess of 10 inches per minute, the cylinder is locked by the velocity fuse and prevents further damage in the containment vessel. Many of these huge shock absorbers are located strategically within the superstructure of the power plant.

One of the conditions of the sale was that Milwaukee Cylinder had to simulate the conditions of an earthquake in order to test and to demonstrate the capability of the product. Cylinders were tested in a lab that had huge machines for testing railroad equipment. An instrumented cylinder had a 35,000 lb. load dropped directly on the cylinder rod end to demonstrate the pressure build-up (in 8 milliseconds), the closing of the valve, and the time required to do so. Milwaukee Cylinder and customer engineers were on site for the tests.

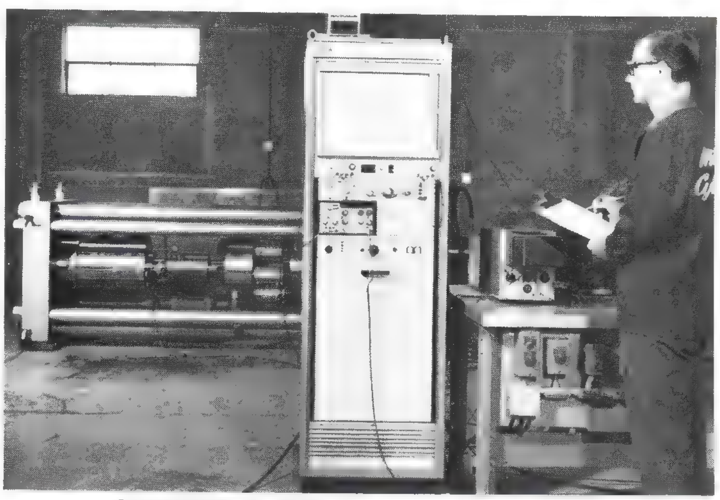
Milwaukee Cylinder also had to provide X-Y plots through an MTS controller in order to specify the personality of each cylinder. Cylinders were placed in a huge test cell and were subjected to extreme hydraulic loads to measure breakaway, leakage, and valve closing. Certified test reports were submitted for each cylinder.

There was ongoing cooperation between the prime manufacturer and Milwaukee Cylinder. The pecularities of hydraulic forces, the compressibility of the fluids, the radioactive contaminant problems with oils and seals all had to be qualified within our engineering and test programs. All these cylinders were built to rigid government specifications. This was a demanding project which was completed very successfully.

Although we are no longer producing for the nuclear field, these efforts demonstrate our engineering, manufacturing, and testing know-how.


SNUBBER ASSEMBLY


SNUBBER PAINTING


SNUBBER TESTING

Fluid Power Formulas

FORMULA FOR:	WORD FORMULA:		LETTER FORMULA:
FLUID PRESSURE *In Pounds/Square Inch*	PRESSURE	$= \dfrac{\text{FORCE } (\textit{pounds})}{\text{UNIT AREA } (\textit{Square Inches})}$	$P = \dfrac{F}{A}$ or psi $= \dfrac{F}{A}$
CYLINDER AREA *In Square Inches*	AREA	$= \pi \times \text{RADIUS}^2 \ (\textit{Inches})$	$A = \pi r^2$
		$= \dfrac{\pi}{4} \times \text{Diameter}^2 \ (\textit{Inches})$	$A = \dfrac{\pi D^2}{4}$ or $A = .785D^2$
CYLINDER FORCE *In Pounds, Push or Pull*	FORCE	$= \text{PRESSURE (psi)} \times \text{NET AREA } (\textit{Square Inches})$	$F = \text{psi} \times A$ or $F = PA$
CYLINDER VELOCITY or SPEED *In Feet/Second*	VELOCITY	$= \dfrac{231 \times \text{FLOW RATE } (\textit{GPM})}{12 \times 60 \times \text{NET AREA } (\textit{Square Inches})}$	$v = \dfrac{231Q}{720A}$ or $v = \dfrac{.3208Q}{A}$
CYLINDER VOLUME CAPACITY *In Gallons of Fluid*	VOLUME	$= \dfrac{\pi \times \text{RADIUS}^2 \ (\textit{Inches}) \times \text{STROKE } (\textit{Inches})}{231}$	$V = \dfrac{\pi r^2 \ell}{231}$
		$= \dfrac{\text{NET AREA } (\textit{Square Inches}) \times \text{STROKE } (\textit{Inches})}{231}$	$V = \dfrac{A \ell}{231}$ ℓ = *Length of Stroke*
CYLINDER FLOW RATE *In Gallons Per Minute*	FLOW RATE	$= \dfrac{12 \times 60 \times \text{VELOCITY } (\textit{Feet/Sec}) \times \text{NET AREA } (\textit{Square Inches})}{231}$	$Q = \dfrac{720vA}{231}$ or $Q = 3.117vA$
FLUID MOTOR TORQUE *In Inch Pounds*	TORQUE	$= \dfrac{\text{PRESSURE } (\textit{psi}) \times \text{F.M. DISPLACEMENT } (\textit{Cu. In./Rev.})}{2\pi}$	$T = \dfrac{\text{psi } d}{2\pi}$ or $T = \dfrac{Pd}{2\pi}$
		$= \dfrac{\text{HORSEPOWER} \times 63025}{\text{RPM}}$	$T = \dfrac{63025 \text{ HP}}{n}$
		$= \dfrac{\text{FLOW RATE } (\textit{GPM}) \times \text{PRESSURE } (\textit{psi}) \times 36.77}{\text{RPM}}$	$T = \dfrac{36.77QP}{n}$ or $T = \dfrac{36.77Q\text{psi}}{n}$
FLUID MOTOR TORQUE / 100 psi *In Inch Pounds*	TORQUE/100 psi	$= \dfrac{\text{F.M. DISPLACEMENT } (\textit{Cu. Inches/Revolution})}{.0628}$	$T_{100\text{psi}} = \dfrac{d}{.0628}$
FLUID MOTOR SPEED *In Revolutions/Minute*	SPEED	$= \dfrac{231 \times \text{FLOW RATE } (\textit{GPM})}{\text{F.M. DISPLACEMENT } (\textit{Cu. Inches/Revolution})}$	$n = \dfrac{231Q}{d}$
FLUID MOTOR POWER *In Horsepower Output*	HORSEPOWER	$= \dfrac{\text{TORQUE OUTPUT } (\textit{Inch Pounds}) \times \text{RPM}}{63025}$	$HP = \dfrac{Tn}{63025}$
PUMP OUTLET FLOW *In Gallons/Minute*	FLOW	$= \dfrac{\text{RPM} \times \text{PUMP DISPLACEMENT } (\textit{Cu. In./Rev.})}{231}$	$Q = \dfrac{nd}{231}$
PUMP INPUT POWER *In Horsepower Required*	HORSEPOWER INPUT	$= \dfrac{\text{FLOW RATE OUTPUT } (\textit{GPM}) \times \text{PRESSURE } (\textit{psi})}{1714 \times \text{EFFICIENCY } (\textit{Overall})}$	$HP_{IN} = \dfrac{QP}{1714\text{Eff}}$ or $\dfrac{\text{GPM} \times \text{psi}}{1714\text{Eff}}$
FLOW RATE THROUGH PIPING *In Feet/Second Velocity*	VELOCITY	$= \dfrac{.3208 \times \text{FLOW RATE THROUGH I.D. } (\textit{GPM})}{\text{INTERNAL AREA } (\textit{Square Inches})}$	$v = \dfrac{.3208Q}{A}$
COMPRESSIBILITY OF OIL *In Additional Required Oil To Reach Pressure*	ADDITIONAL VOLUME	$= \dfrac{\text{PRESSURE } (\textit{psi}) \times \text{VOLUME OF OIL UNDER PRESSURE}}{250{,}000}$	$V_A = \dfrac{PV}{250{,}000}$ [Approximately ½% Per 1000 psi]

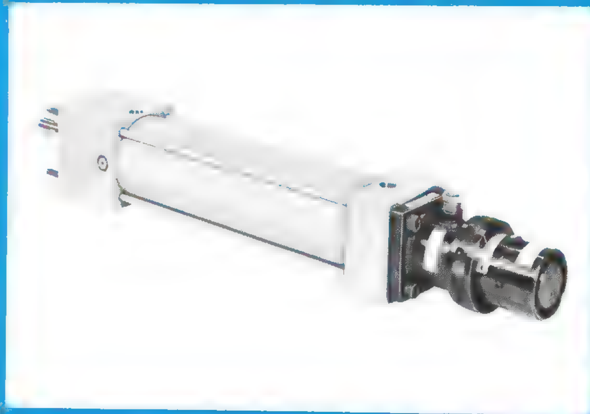
GAS LAWS FOR ACCUMULATOR SIZING

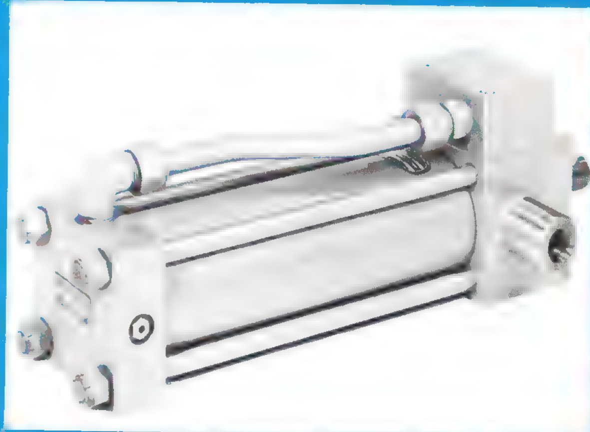
Where "P" = psia *(ABSOLUTE)* **= psig** *(GAUGE PRESSURE)* **+ 14.7 psi**

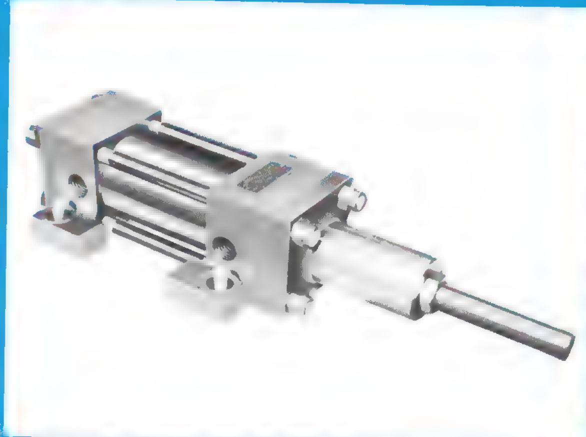
FORMULA FOR:	WORD FORMULA:	LETTER FORMULA:
PRESSURE OR VOLUME *w/Constant "T" (Temperature)*	ORIGINAL PRESSURE x ORIGINAL VOLUME = FINAL PRESSURE x FINAL VOLUME	$P_1 V_1 = P_2 V_2$ [Isothermic]
PRESSURE OR TEMPERATURE *w/Constant "V" (Volume)*	ORIGINAL PRESSURE x FINAL TEMPERATURE = FINAL PRESSURE x ORIG. TEMP.	$P_1 T_2 = P_2 T_1$ [Isochoric]
VOLUME OR TEMPERATURE *w/Constant "P" (Pressure)*	ORIGINAL VOLUME x FINAL TEMPERATURE = FINAL VOLUME x ORIGINAL TEMP.	$V_1 T_2 = V_2 T_1$ [Isobaric]
PRESSURE OR VOLUME *w/Temperature Change Due To Heat of Compression*	ORIGINAL PRESSURE x ORIGINAL VOLUME^n = FINAL PRESSURE x FINAL VOLUME^n	$P_1 V_1^n = P_2 V_2^n$
	$\dfrac{\text{FINAL TEMP.}}{\text{ORIG. TEMP.}} = \left(\dfrac{\text{ORIG. VOLUME}}{\text{FINAL VOLUME}}\right)^{n-1} = \left(\dfrac{\text{FINAL PRESSURE}}{\text{ORIG. PRESSURE}}\right)^{n-1/n}$	$\dfrac{T_2}{T_1} = \left(\dfrac{V_1}{V_2}\right)^{n-1} = \left(\dfrac{P_2}{P_1}\right)^{n-1/n}$

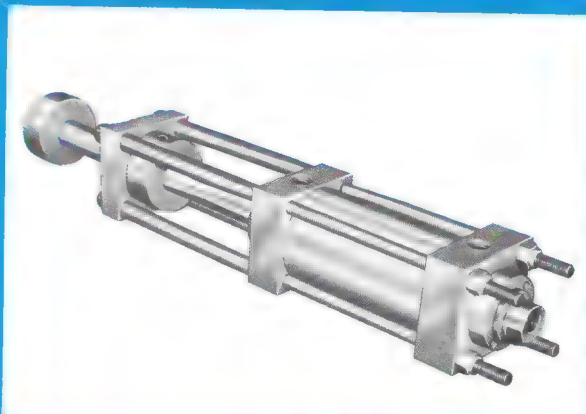
FOR NITROGEN THE EXPONENT "n" = 1.4 For full adiabatic conditions i.e., the "Full Heating" theoretical condition
"n" = 1.3 For rapid cycling (most heating normally experienced)
"n" = 1.1 For "Normal" cycling
"n" = 1.0 Where gas time to return to normal temp. before discharge or recharge

Special Applications









High Cycling Requirements

The life of a standard industrial cylinder is greatly reduced under high speed cycling unless it is equipped with 3″ to 4″ long cushions. This will not only reduce the shock effect, but will also considerably reduce the cycle speed. When high cycling cylinders are required, Milwaukee can install a standard, commercial grade shock absorber on the blind end of the cylinder. This can substantially increase the effective cushion length. If you need more specific information on the use of shock absorbers for high cycling rates, please let us know.

Ported Trunnion, Safety Cylinder

The manufacturer of a food compactor needed a cylinder with two specific requirements: 1. The blind end of the cylinder had to have complete freedom of movement around the rod end with no interference from pipe or tubing. 2. The compactor must be safe when open . . . the cylinder must automatically lock in the extended position . . . even with a loss of hydraulic pressure. Milwaukee solved the first problem by bringing the lines directly through the trunnions. To meet the second requirement, a pilot operated cartridge check valve had to be externally mounted on the rod end cap. Another Milwaukee Cylinder special use solution.

Adjustable Stroke Cylinder

From its long experience in making special modifications to standard cylinders, Milwaukee can usually come up with an inexpensive answer to an application requirement. In this application, the extend cycle of the cylinder had to be adjustable for different lengths. Milwaukee attached a special, welded stop around one of the double rod ends. The rod end going through the stop has an easily adjustable nut that will precisely set the length of the extend cycle.

Adjustable Stop Cylinder

Like the cylinder above, this one does not require special valving in order to achieve an adjustable stroke length. But unlike the other cylinder, the length of the stroke had to be adjustable in both directions. In this case, the blind end flange had an extension added through which one of the double rod ends passed. Around the rod were attached two, threaded, locking collars for quick and easy adjustment of the rod travel in either direction.

Fluids and Seals

FLUIDS

Hydraulic fluid is much more than the theoretician's incompressible medium. It heats, cools, lubricates and sometimes corrodes mechanical components, picks up and releases gases, and sweeps sludge into supposedly free clearances. The fluid is just as important as any other part of the hydraulic system. In fact, a major portion of hydraulic problems stem from the use of improper types of fluids or fluids containing dirt and other contaminants.

To understand the fluids used in today's industry, you have to divide them into two general areas: petroleum fluids and fire resistant fluids. These in turn break down into a number of different types with different properties. Not all fluids are compatible with the standard seal combinations offered by cylinder manufacturers.

In the chart below is a small sample of the fluids available and the seals with which they are compatible. Specific information on seal compatibility is available from either the fluid supplier or the component manufacturer.

SEALS

Buna N Seal

This type of seal is excellent with petroleum products. The seal is rated for a temperature range from -65° F to +250° F, but when used for low temperatures, it is necessary to sacrifice some low temperature resistance. It is a superior material for compression set, cold flow, tear and abrasion resistance.

This seal is generally recommended for:

• Petroleum • Water • Diester • Water-Glycol

Polyurethane Seal

The polyurethane seal provides excellent mechanical and physical properties. Polyurethane does not provide a good low pressure seal due to its poor compression and permanent set properties.

This seal is generally recommended for:

• Petroleum • Water/Oil • Phosphate Ester

Ethylene Propylene

This seal is excellent when used with Skydrol 500 and Phosphate Ester Fluids. The seal is rated for a temperature range from -65° F to +350° F.

This seal is generally recommended for:

• Phosphate Ester • Steam (to 400° F) • Water • Ketones

Viton Seal

Viton seals are compatible with a wide range of fluids. This seal is rated for a temperature range from -20° F to +350° F.

This seal is generally recommended for:

• Petroleum • Silicate Ester • Diester • Halogenated Hydrocarbons
• Most Phosphate Esters

SEAL COMPATIBILITY WITH COMMON FLUIDS

Fluid Name	Military Specification	Mfg. No.	Trade Name/Number	Buna N	Polyurethane	EP	Viton Fluorocarbon
Water Glycol		1	Houghto-Safe 600 Series	R	U	R	S
		1	Houghto-Safe 500 Series	R	U	R	—
	MIL-H22072	1	Houghto-Safe 271 Series	R	U	R	S
		4	Ucon Hydrolube	R	U	R	R
		5	Celluguard	R	U	R	R
Water Oil/Emulsion		1	Houghto-Safe 5040	R	U	U	R
		3	Gulf FR	R	R	U	R
Water Soluble Oil		—	—	R	—	R	—
Water Fresh		—	—	R	U	R	R
Water Salt		—	—	R	U	R	R
Phosphate Ester		1	Houghto-Safe 1000 Series	U	U	R	R
	MIL-19547B	1	Houghto-Safe 1120	U	U	R	R
		8	Pyrogard 42, 43, 53, 55	U	U	R	R
		2	Skydrol 500 Type 2	U	—	R	U
		2	Skydrol 7000 Type 2	U	—	R	U
Diester	MIL-H-7808	—	Lube Oil Aircraft	S	U	U	R
Silicate Ester	MIL-H-8446B	7	Brayco 846	S	R	U	R
Kerosene		—	—	R	R	U	R
Jet Fuel	MIL-J-5624	—	JP-3,4,5 (RP-1)	R	R	U	R
Diesel Fuel		—	—	R	M	U	R
Gasoline		—	—	R	U	U	R
Petroleum Base	MIL-H-6083	—	Preservative Oil	R	R	U	R
	MIL-H-5606	—	Aircraft Hyd. Fluid	R	R	U	R

Manufacturer No:

1. E. F. Houghton
2. Monsanto
3. Gulf
4. Union Carbide & Chemical
5. Stauffer Chemical
6. Standard Oil (Ortho Chemical)
7. Bray Oil — Royal Lubricant
8. Mobil Oil

Seal Compatibility

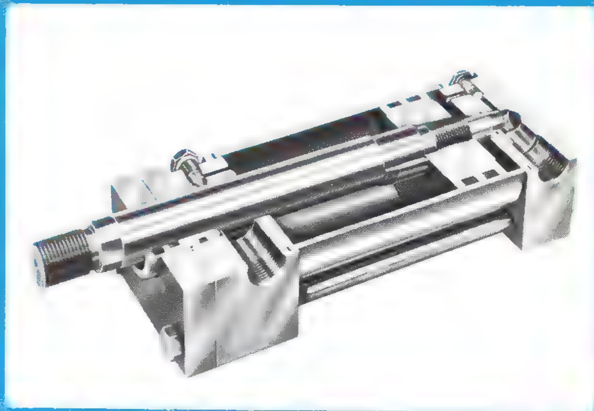
R = recommended
S = satisfactory
M = marginal
U = unsatisfactory
— = insufficient data

Note:

The above chart is for general information and should not be taken as warranty or representation for which legal responsibility is assumed. The chart and the information on this page is offered only for your convenience, consideration, investigation, and verification.

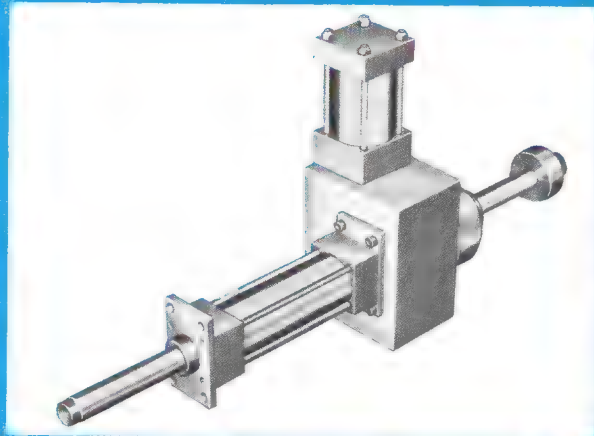
Pre-lubricated "AL" Cylinders

A completely oil-free system can now be maintained for pollution-free atmospheres. The new Milwaukee "AL" air cylinders have been pre-lubricated with a special, extremely low viscosity plasticized chemical for millions of maintenance free cycles. Excellent for food, drug, and chemical processing, for fabric production, or in automotive manufacturing. Laboratory tests indicate over 11,000,000 cycles of normal operation (18" stroke, 6 lb. side load). Internal improvements include floating cushions on both ends, cast iron piston, improved bearings, and hard chrome plating on the ID of the cylinder barrel. Available in all sizes and mounting styles through 6" bores.



Double Cylinder Combination

Here's a piggyback combination that mates two cylinders of different sizes for two entirely different type jobs on a plastic bottle production line. The longer cylinder has a hollow rod for the purpose of extruding the bottle. Because of different size requirements on the same line, an adjustable stop had to be engineered into the double rod extension on the rear of the cylinder. The other cylinder has a rod that is linked to the longer cylinder's rod, through their common mounting, and rotates the latter rod in order to cut off the neck of the bottle after forming. An involved problem solved by Milwaukee.

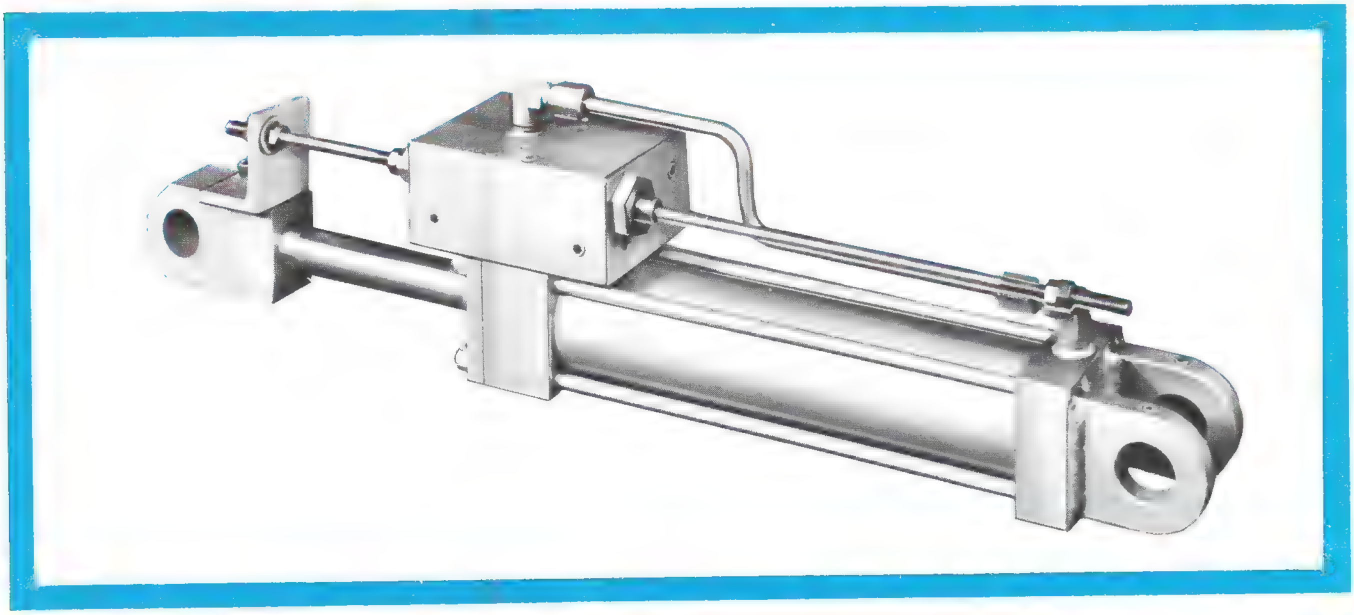


Nose Mounted Cylinder

Milwaukee Cylinder has built many types of replacement cylinders for repairing foreign machinery. In most cases these cylinders do not conform to NFPA specifications. This particular cylinder was designed to replace a cylinder built in Europe. A special threaded nozzle was required for mounting purposes.

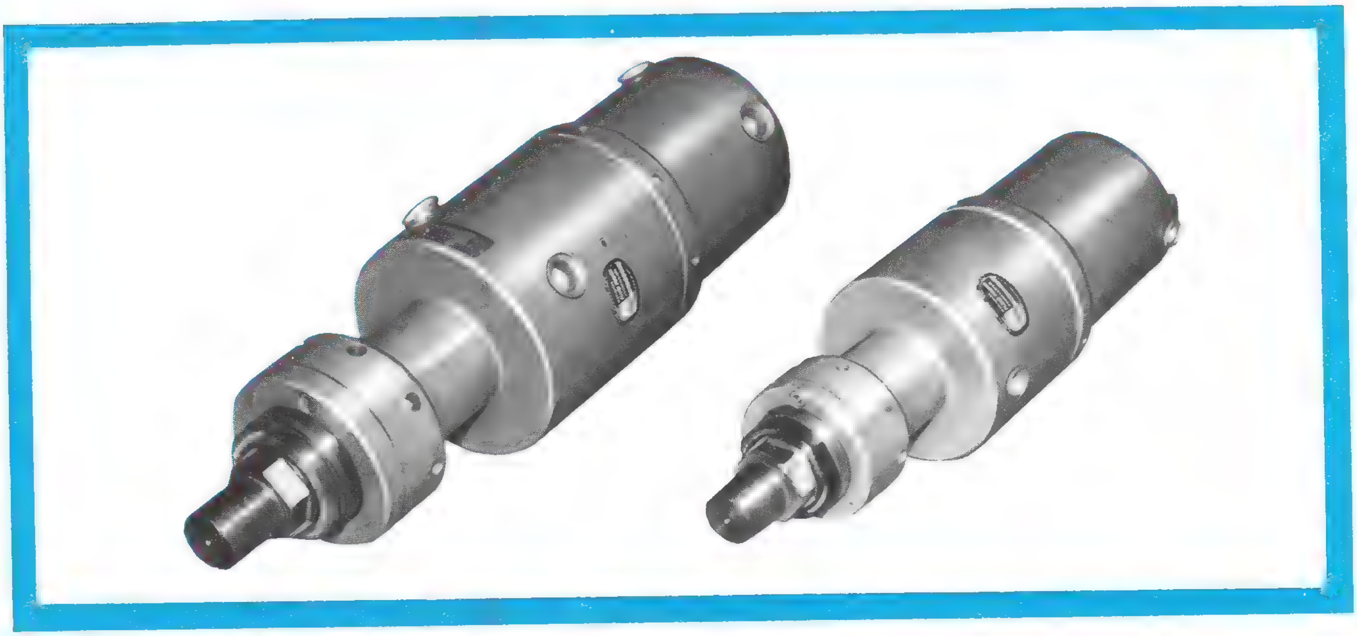
5,000 psi Cylinder

Milwaukee has the design and engineering capability and the manufacturing facilities and equipment to produce large, specially built cylinders in the 5,000 psi pressure range. This cylinder has special mountings and extra heavy duty construction to support its bore, stroke and rod. The internally threaded rod has internal rod seals with a removable gland to allow mounting requirements to be met.



Reciprocating Cylinders

This cylinder was designed for use on an automatic farm irrigation system. Its reciprocating action propels wheels on an irrigation tower in order to move the combined system in a complete circle around a central pivot and water supply point. Reliability of the cylinder is a must as the units have to operate for extended periods without attendance. One of the special design features in the integral valve package is the elimination of a neutral position at crossover to allow for either fast or slow operation. Thousands of these cylinders have now been in operation on farms throughout the country for many years. This type of actuator has also been used in car washers and in reciprocating grinding operations.



Heavy Duty Cylinders

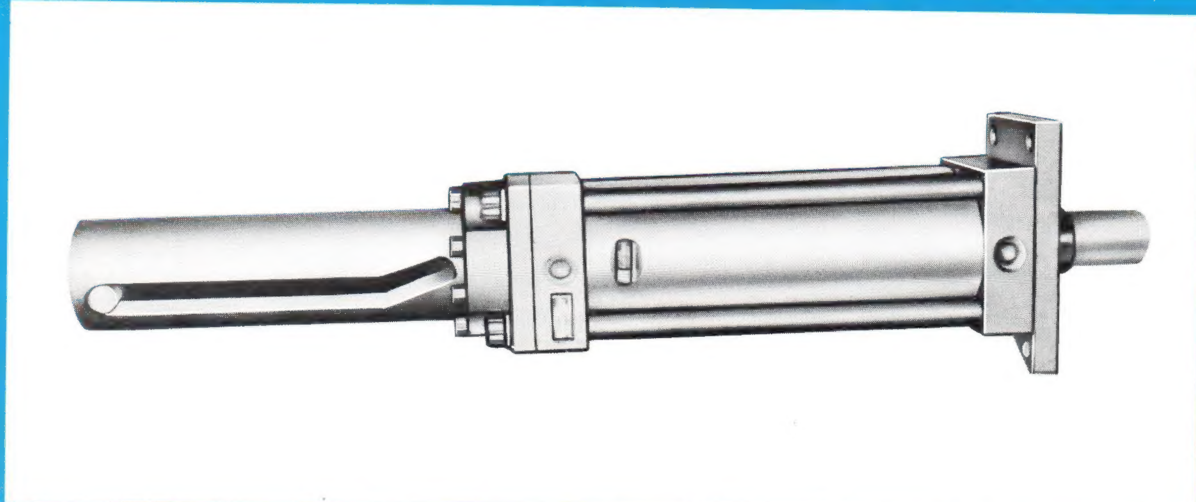
The Series HD cylinder is a heavy duty, non tie rod design rated for continuous 5,000 psi operation. It has been designed specifically for punching and piercing operations in thick metal requiring tonnage ratings from 17-1/2 to 100 tons. These cylinders have been successfully used for gang punching of automobile frames. Series HD cylinders are made for neck mounting through a hole in a heavy duty frame. A locking type, split ring collar holds the cylinder in position. HD cylinders will accommodate severe side loads.

Internal Bearing Cylinder

This cylinder is required to lift the door of a furnace in a foundry operation. In doing so, a high side load would be generated, requiring an extra long bearing and internal guide on the rod. Milwaukee engineers designed in a 32" long, internal bearing with a rod cushion threaded into the gland. There is a metric thread on the 9" ram. The tube is self-supporting with the blind end, which is the mounting end, welded on.

Controlled Rotating Cylinder

Sand shell cores for casting turbine rotors required a large cam roll and three men to turn the cope. Due to the curved blades on the rotor, the cope of the pattern had to be rotated as it was being removed. Milwaukee engineers developed a precision cylinder in which the rod would rotate during the first two inches of upward travel . . . and travel straight up for eleven more inches. An extended tube on the blind end of the cylinder is grooved to match the required rotation of the rod. A cam roller mounted on a tail rod rides in the groove and provides the required rotation of the piston rod. This controlled rotation released the blades in the pattern from the sand core in a predetermined manner without incurring breakage.



Glossary of Fluid Power Terms

"Terms and definitions are extracted from ANSI Glossary of Terms for Fluid Power with permission of the publisher, National Fluid Power Association, Milwaukee, Wisconsin 53222."

Accumulator - a container in which fluid is stored under pressure as a source of fluid power.
Air, Compressed - air at any pressure greater than atmospheric pressure.

Bleeder, Air - a device for the removal of air from an oil system.
Breather, Air - a device permitting air movement between the atmosphere and the component in which it is installed while preventing contaminants from entering the component.

Cap, Blind End - a cylinder end closure which completely covers the bore area.
Cap, Rod End - The cylinder end enclosure which covers the differential area between the bore area and the piston rod area.
Cavitation - a localized gaseous condition within a liquid stream which occurs where the pressure is reduced to the vapor pressure.
Clevis - a "U" shaped mounting device which contains a common pin hole at right angle or normal to the axis of symmetry through each extension.
Compressibility - the change in volume of a unit of volume of a fluid when subjected to a unit change of pressure.
Cycle - a single complete operation consisting of progressive phases starting and ending at the neutral position.
Cushion - a device which provides controlled resistance to motion.
Cushion, Cylinder - a cushion built into the cylinder to restrict flow at the outlet port thereby arresting the motion of the piston rod.
Cylinder - a device which converts fluid power into linear mechanical force and motion.
Cylinder, Adjustable Stroke - a cylinder equipped with adjustable stops at one to limit piston travel.
Cylinder, Double Acting - a cylinder in which fluid force can be applied to the moveable element in either direction.
Cylinder, Non-Rotating - a cylinder in which the relative rotation of the cylinder housing and the piston and piston rod, plunger or ram, is fixed.
Cylinder, Single Acting - a cylinder in which the fluid force can be applied to the moveable element in only one direction.
Cylinder, Tandem - two or more cylinders with interconnected piston assemblies.

Durometer Hardness - a measure of elastomer hardness by use of a durometer.

Filter - a device whose primary function is the retention by porous media of insoluble contaminants from a liquid.
Fitting - a connector or closure for fluid power lines and passages.
Flow, Laminar - a flow situation in which fluid moves in parallel laminar or layers.
Flow Rate - the volume, mass, or weight of a fluid passing through any conductor per unit of time.
Flow, Turbulent - a flow situation in which fluid particles move in a random manner.
Fluid Friction - friction due to the viscosity of fluids.
Fluid Stability - resistance of a fluid to permanent changes in properties.

Gage - an instrument or device for measuring, indicating, or comparing a physical characteristic, such as pressure or volume.

Hydraulic Pump - a device which converts mechanical force and motion into fluid power.

Intensifier - a device which converts low pressure fluid power into high pressure fluid power; also called a booster.

Lubricator - a device which adds controlled or metered amounts of lubricant into an air system.

Manifold - a conductor which provides multiple connection ports.
Muffler - a device for reducing gas flow noise.

Packing - a sealing device consisting of bulk deformable material or one or more mating deformable elements, reshaped by manually adjustable compression to obtain and maintain effectiveness. It usually used axial compression to obtain radial sealing.
Port - an internal or external terminus of a passage in a component.
Port Bleed - a port which provides a passage for the purging of gas from a system or component.
Port, Cylinder - a port which provides a passage to or from an actuator.
Port, Exhaust - a port which provides a passage to the atmosphere.
Pressure - force per unit area, usually expressed in pounds per square inch.
Pressure, Burst - the pressure which creates loss of fluid thru the component envelope, resulting from failure.
Pressure, Cracking - the pressure at which a pressure operated valve begins to pass fluid.
Pressure, Operating - the pressure at which a system is operated.
Pressure, Peak - the maximum pressure encountered in the operation of a component.
Pressure, rated - the qualified operating pressure which is recommended for a component or a system by the manufacturer.
Pressure, Shock - the pressure existing in a wave moving at sonic velocity.
Pressure, Static - the pressure in a fluid at rest.
Pressure, Surge - the pressure existing from surge conditions.
Pressure, Working - the pressure at which the working device normally operates.
Pressure Vessel - a container which holds fluid under pressure.

Reservoir - a container for the storage of liquid in a fluid power system.
Restrictor - a device which reduces the cross-sectional flow area.
Reyn - the standard unit of absolute viscosity in the English system. It is expressed in pound-seconds per square inch.

Servovalve - a valve which modulates output as a function of an input command.
Silencer - a device for reducing gas flow noise. Noise is decreased by tuned resonant control of gas expansion.
Subplate - an auxiliary ported plate for mounting components.
Surge - a transient rise of pressure or flow.

Tube - a line whose size is its outside diameter. Tube is available in varied wall thicknesses.

Valve - a device which controls fluid flow direction, pressure, or flow rate.
Valve, Directional Control - a valve whose primary function is to direct or prevent flow through selected passages.
Valve, Flow Control - a valve whose primary function is to control flow rate.
Valve, Sequence - a valve whose primary function is to direct flow in a predetermined sequence.
Valve Position, Detent - a predetermined position maintained by a holding device acting on the flow-directing elements of a directional control valve.
Valve Position, Normal - the valve position when signal or actuating force is not being applied.
Viscosity - a measure of internal friction or the resistance of a fluid to flow.

“We Are Personally Involved”

Yes, we are personally involved . . .

The prime objective of our organization is to serve our industry with expertise in design and high performance products that satisfy the exact needs of our customers, be it standard or special products . . . This is our position in the market.

Our advertising theme, “SPECIALS ARE STANDARD AT MILWAUKEE”, points up our stated objectives.

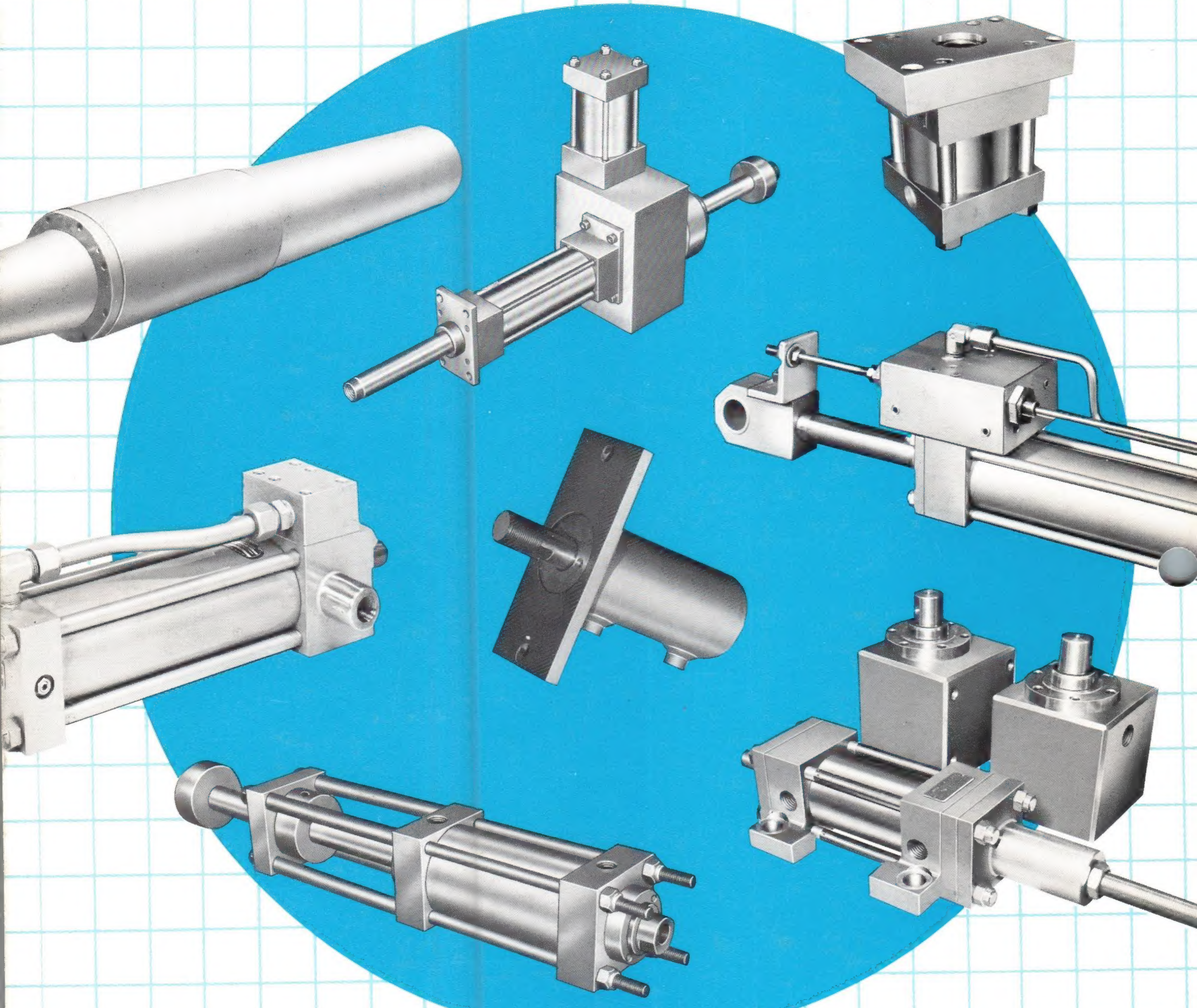
Todays machinery builders and designers are faced with stiff competition both at home and abroad. It’s a real challenge to remain competitive, to offer new design advantages plus the quality and performance necessary to remain a leader.

For the past 15 years we have addressed ourselves to this important need in the Fluid Power market. To accomplish this objective, Milwaukee Cylinder offers an experienced, highly technical team of engineers and manufacturing people. Our experience over the years covers a great variety of special fields and applications from simple machines to complicated robots.

We are very proud of our reputation as a top quality designer and manufacturing company, and we are anxious to offer our experience and proven talents and facilities to you and your organization.

Our future and reputation are dedicated to serve you with the best in high quality products and with the service to match. Everyone on our team is personally involved to serve this end.

For your cylinder needs . . .



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